ARI Research Note 88-34

TARGET ACQUISITION AND ANALYSIS TRAINING SYSTEM: AN EXPLORATORY INVESTIGATION OF VEHICLE IDENTIFICATION PERFORMANCE WITH BLACK HOT AND WHITE HOT THERMAL IMAGES

Otto H. Heuckeroth
Norman D. Smith
Army Research Institute

William L. Warnick
Essex Research Group

for

ARI Field Unit at Fort Hood, Texas
George M. Gividen, Jr., Chief

SYSTEMS RESEARCH LABORATORY
Robin L. Keesee, Director

U. S. Army

Research Institute for the Behavioral and Social Sciences

April 1988

U. S. ARMY RESEARCH INSTITUTE

FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency under the Jurisdiction of the

Deputy Chief of Staff for Personnel

EDGAR M. JOHNSON
Technical Director

WM. DARRYL HENDERSON
COL, IN
Commanding

Technical review by

George M. Gividen

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARI Research Note 88-34	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Target Acquisition and Analysis Training System: An Exploratory Investigation of Vehicle Identification Performance with Black Hot and White Hot Thermal Images		5. TYPE OF REPORT & PERIOD COVERED Interim Report June - July 1984
		6. PERFORMING ORG. REPORT NUMBER - -
7. AUTHOR(s) Otto H. Heuckeroth, Norman D. Smith, and William L. Warnick		8. CONTRACT OR GRANT NUMBER(s) - -
9. PERFORMING ORGANIZATION NAME AND ADDRESS ARI Field Unit at Fort Hood, Texas HQ TEXCOM PROV Fort Hood, TX 76544-5065		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2Q263744A795 3.2.1.H.1
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Avenue, Alexandria, VA 22333-5600		12. REPORT DATE May 1988
		13. NUMBER OF PAGES 24
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) - -		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE - -

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

- -

18. SUPPLEMENTARY NOTES

- -

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Vehicle Identification	White Hot
Combat Vehicle Identification	Black Hot
Polarity Setting	
Thermal Imagery	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This research note reports on research whose major objectives were to determine: 1) how overall identification performance differs between slides of black hot and white hot thermal vehicle images, and 2) how identification performance is affected by whether the images shown at various ranges are black hot or white hot.

The primary conclusions drawn from the data analyses included these:

-- The black hot thermal polarity setting is preferred for target identification by the majority of soldiers who are competent in vehicle (OVER)

DD FORM 1473 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

ARI RESEARCH NOTE 88-34

20. Abstract (continued)

recognition and identification using thermal sights.
-- Although an average of absolute differences between performance using black hot and white hot images favored the use of black hot images across all ranges, these results are inconclusive. Further research is suggested.
-- Identification performance using thermal images degrades sharply at intermediate (1300-1700 meter) and far (1800-2300 meter) ranges.

imagery, target acquisition

TARGET ACQUISITION AND ANALYSIS TRAINING SYSTEM: AN EXPLORATORY INVESTIGATION OF VEHICLE IDENTIFICATION PERFORMANCE WITH BLACK HOT AND WHITE HOT THERMAL IMAGES

CONTENTS

LIST OF TABLES

Contents (continued)

FIGURE

INTRODUCTION

Background

In 1980, the Target Acquisition and Analysis Training System (TAATS), a part of the research program at the Army Research Institute's Field Unit, Fort Hood, Texas, was established. The major objective of TAATS was to provide a framework within which to develop a series of interrelated target acquisition training programs. Five have been developed, tested and turned over to the Army. They are the Basic Combat Vehicle (CVI) Training Program, the Basic Thermal Combat Vehicle Identification (TCVI) Training Program, the Advanced Combat Vehicle Training Program, the Flash Card Program and The Combat Vehicle Training Program for the Remotely Piloted Vehicle (RPV). The first two programs, the CVI and TCVI, have been adopted and issued by the Army as standardized and official training for vehicle identification and are designated as GTA 17-2-9 and GTA 17-2-10, respectively.[1] The CVI Flash Cards have been issued as GTA 17-2-11. The Advanced CVI awaits funding. The RPV program was used to train operators during the Operational Test (OT) II in June, 1982 and a final program is now under consideration.

Military Problem

When IR sensing systems were first added to such weapons systems as the TOW in the 1970s, engineeers at the Night Vision Laboratory, now Night Vision and Electro Optics Laboratory (NV&EOL), made a decision based on "user" comments that a polarity switch would not be included. Functionally the polarity switch permits the operator to view the images of hot objects as either black or white, thus the terms black hot or white hot.

In ARI's development of the thermal CVI (TCVI) program, use of black hot images was possible because current systems such as the TIS and TTS have a polarity control. This capability helped overcome the hypothesized handicap found with earlier systems which permitted only white hot images. Specifically, as range increases it was judged that the white hot image looses definition and sharpness and tends to bloom, thus making the image less suitable for R&I.

Prior to this research there were no data on vehicle identification performance with thermal images which demonstrated the relationship between range and polarity selection. The current research provides a preliminary evaluation of that relationship.

---

[1] A citation for the technical or research report on each of the training programs is in the Reference section.

METHOD

Subjects

A total of 100 soldiers from the 2AD at Fort Hood, Texas participated in this research. Each soldier selected was a tank crew member or IFV crew member with experience in use of the Thermal Integrated Sight (TIS), the Tank Thermal Sight (TTS) or the Integrated Sight Unit (ISU). Demographic and background characteristics for these soldiers are summarized in Table 7 of the Results section.

Procedure

For purposes of this preliminary investigation and because of time, personnel, range, and equipment limitations it was neither cost effective nor feasible to attempt to have all 100 subjects actually view all vehicles through thermal sights at each range required. An alternative method was therefore employed. Thirty-five millimeter slides were made from photographs taken through thermal sights. All 12 vehicle types used were photographed with both black hot and white hot polarity settings at each required range. These slides of thermal images were then viewed by the soldiers. One advantage of this method is that it provided controls over the quality and consistency of the thermal images presented that would not otherwise have been possible.

All imagery was obtained as seen through the TIS (M1) and TTS (M60A3) sights. Imagery for use in this evaluation was collected under the following conditions. A research psychologist, a technician and a tank commander, all familiar with TIS and TTS imagery unanimously determined that the sight was optimally set for each image for focus, sensitivity and contrast. A wave form monitor was used to verify the settings. Vehicle images were recorded at 100 meter intervals starting at 2300 meters and ending at 600 meters. While changes in weather conditions, instrument performance, and sight functioning caused some variability in image quality, every effort was made to obtain the best possible black hot and white hot thermal imagery available.

From this data base the 35mm slides were created to form the training and test stimuli for its research. Black hot and white hot images for each vehicle at each range were matched on quality by an expert on thermal imagery. The array was then evaluated by two different researchers familiar with thermal imagery as to the acceptability or unacceptability of the match. The quality obtained was judged sufficient for use in this preliminary evaluation.

Soldiers were divided into four groups of 25 to facilitate the two hours of planned training/testing on each of four days. On the first day, soldiers were pre-tested for identification proficiency with one black hot and one white hot image for each of 12 vehicles at each range category (800-1200 meters, 1300-1700 meters, and 1800-2300 meters) for a total of 72 slides. In all training/testing only oblique or side view images of vehicles were used; no front views were used. Soldiers were then given a short session with photopic images. Over the remaining time soldiers were trained to identify black hot and white hot images of each of the 12 vehicles as seen at the shortest range

of 800-1200 meters. After approximately five hours of training, soldiers were given a post-training test to evaluate training level attained. This post-training test included three black hot and three white hot slides for each of the 12 vehicles at the short range category of 800-1200 meters (for a total of 72 slides). Training at this relatively close range was designed to maximize the chances that soldiers would learn the thermal black hot and white hot images for each vehicle. It was reasoned that if soldiers knew these images, then performance exhibited at the same or other ranges a short time later would be primarily a function of image identification difficulty at different ranges and not a function of how well the images had been learned. All soldiers were then given a second post-training test.[1] During this latter test each vehicle was presented six times at each of the three range categories; three times black hot, three times white hot (108 black hot and 108 white hot for a total of 216 slides).

Equipment

Standard military issue 35mm Kodak carrousel slide projectors with zoom lens were used. The screen consisted of a 2' x 3' piece of poster board securely attached to a speakers lectern.

Chairs with writing-arms were usually available. When not, clipboards were used.

Data Collection Instruments

Soldier responses to pre-training test, post-training test and the final post-test were recorded on a simple form calling for basic background information and list of slide numbers with a position to record each vehicle identification. At completion of the training/testing soldiers were asked to complete a short evaluation questionnaire. Responses to that questionnaire are found together with tabulated background information in Table 7 of the Results section.

Data Analysis

Since one of the major purposes of this research effort was to determine the relative efficacy of black hot and white hot imagery on identification performance at different ranges, soldiers were provided training which was intended to produce mastery. Examination of post-training test performance indicated, however, that even with the repeated training on relatively few vehicles, mastery was not attained by most soldiers. In order to assess performance differences relatively independent of the effects of learning differences, only soldiers who attained 80% or better correct identifications in the post-training test were included in subsequent analyses. A total of 34 soldiers attained this performance level. For these soldiers the post-test data were subjected to a within subjects analyses of variance with vehicles, image polarity and range as the primary variables. Duncan Multiple Range tests

---

[1] This second post-training test utilizing all three range categories is referred to hereafter in this report simply as the "post-test."

were used to assess for which vehicles identification performance differed and for which ranges significant differences existed. Independent analyses of variance were performed for data at each range to better understand for which ranges performance differences between black hot and white hot imagery were significant. In order to assess the relative importance of the different significant effects, the ω^2 statistic for a fixed effects model was used to provide a measure of the proportion of variance each of those effects accounted for in the post-test identification scores.[2]

---

[2] ω^2 is the relevant statistic to report since all effects of interest are based on a fixed-effects model. Approximations to the ω^2 statistics for effects of interest were derived using the procedure outlined by Myers, J. L. Fundamentals of Experimental Design (2nd ed.), Allyn and Bacon, Inc. Boston, 1972, p. 314. A worksheet containing calculations is available upon request.

RESULTS

Results presented in this report address four issues: 1) How overall identification performance differs when using slides of black hot versus white hot thermal vehicle images; 2) How identification performance with black hot and white hot thermal image settings is affected by different ranges; 3) How overall identification performance using thermal images changes at different ranges; and 4) How identification performance differs for each vehicle, independently and in combination with image polarity setting and range. Except for demographic data summarized at the end of this section, all results presented are based on post-test performance of 34 soldiers whose post-training performance was greater than or equal to 80%. As noted in the methodology section, the primary analytic tools used are analysis of variance, Duncan Multiple Range tests, ω^2 (to assess the proportion of variance accounted for in the identification performance by each source of variance considered) descriptive means, and standard deviations.

Image Polarity Settings

Analyses of post-test performance data indicated that, overall, vehicle identification performance is superior with images taken with the black hot polarity setting [$F(1,33) = 24.28$, $p < .001$]. Means and standard deviations of the number of slides identified are summarized in Table 1 below.

Table 1

Means and Standard Deviations of the Number of Slides Identified in the Post-Test for Black Hot and White Hot Polarity Images*

Image Polarity	Mean	Standard Deviation
Black Hot	65.68	6.53
White Hot	60.76	6.09

*n=34; Maximum score = 108

Image Polarity Settings and Range

One major impetus for the present research was based on the belief that at near ranges, identification performance using black hot and white hot images would be about equal but as range increased, performance using black hot images would show increasing superiority over performance using white hot images.

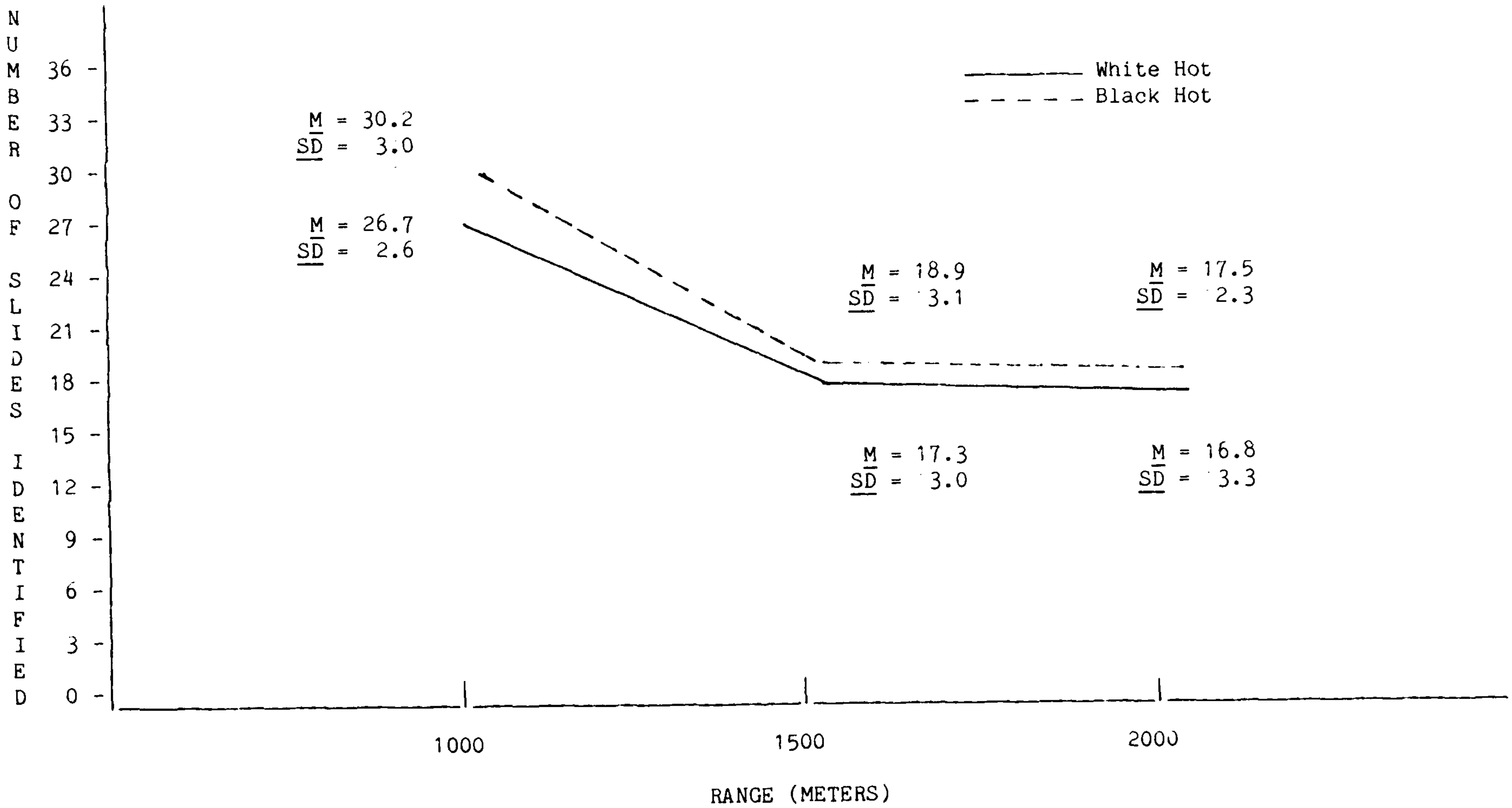

Figure 1. Number of Slides Identified for Black Hot and White Hot Images at Three Average Ranges

(Maximum possible identifications for each polarity for each range = 36.)

Analysis of post-test data did reveal significant performance differences of image type and range [$F(2,66) = 11.51$, $p < .001$]; however, as can be seen in Figure 1, performance differences between polarity types is greatest for near ranges and become smaller as image range increases. Separate analyses of variance for image types at each range showed that only at the near ranges was performance with black hot images significantly superior to white hot images [$F(1,33) = 57.64$, $p < .001$] although at all three ranges used, overall absolute performance differences favored black hot images.

Identification of Thermal Images at Different Ranges

In as much as identification of thermal images depends largely on vehicle shape, as range increases, the differentiating cues between vehicles would be expected to become more difficult to discern. With this rationale, it was predicted that as range increased, identification performance would decrease. Analysis of post-test data revealed significant performance difference as range increases [$F(2,66) = 363.35$, $p < .001$]. A Duncan Multiple Range Test indicated that while performance monotonically decreases as range increases, only performance differences between the near range and other two ranges (medium, far) were significantly different ($p = .05$). Means and standard deviations of number of slides identified at each range are summarized in Table 2.

Table 2

Means and Standard Deviations of the Number of Slides Identified in the Post-Test Using Thermal Images Presented at Near, Medium and Far Ranges ($n = 34$)

Range	Means*	Standard Deviation
Near	56.94 A	4.87
Medium	35.21 B	5.27
Far	34.29 B	4.60

*Means followed by same letter do not differ significantly ($p > .05$). Maximum score = 72.

Identification of Individual Vehicles

In an analysis of variance, identification performance using thermal images shows significant differences in performance for different vehicles [$F(11,363) = 92.58$, $p < .001$]. Means and standard deviations of number of slides identified with black hot or white hot thermal image slides combined are presented in Table 3. More specifically, that analysis of variance also indicated significant performance differences among vehicles presented with different image polarity settings (black hot/white hot) [$F(11,363) = 15.42$, $p < .001$]. Means and standard deviations of number of slides identified for each vehicle in each polarity image are presented in Table 4.

Table 3

Means and Standard Deviations of the Number of Slides Identified in the Post-Test Using Thermal Images of Each Vehicle (n=34)

Vehicle	Means*	Standard Deviation
M113	15.44 A	1.97
M60	15.24 A	1.79
M1	14.50 B	1.85
Quarter Ton	13.94 B C	2.52
M35 (2 1/2 T)	13.26 C	3.48
M109	9.97 D	2.80
M548	9.21 E	2.28
VULCAN	8.26 F	2.21
M577	7.35 G	2.17
M880	7.24 G	2.58
Gamma Goat	6.15 H	1.79
CHAPARRAL	5.88 H	2.01

*Means followed by the same letter do not differ significantly ($p > .05$) according to a Duncan Multiple Range Test. Maximum score = 18.

Table 4

Means and Standard Deviations of the Number of Slides Identified in the Post-Test Using Black Hot and White Hot Images of Each Vehicle (n=34)

	Image Type			
	Black Hot		White Hot	
Vehicles	Mean*	Standard Deviation	Mean*	Standard Deviation
M113	7.88	1.17	7.56	1.16
M60	7.79	1.34	7.44	1.31
M1	7.12	1.25	7.38	0.85
Quarter Ton	8.00	1.23	5.94	1.58
M35 (2 1/2 T)	6.62	1.76	6.65	2.01
M109	5.18	1.59	4.79	1.72
M548	4.88	1.49	4.32	1.20
VULCAN	3.62	1.50	4.65	1.23
M577	5.18	1.51	2.18	1.57
M880	3.68	1.61	3.56	1.81
Gamma Goat	2.91	0.97	3.24	1.33
CHAPARRAL	2.82	1.42	3.06	0.95

* Maximum score = 9.

While overall we have seen that performance on black hot images is higher, test results indicate that for five of the 12 vehicles identification performance appears better for the white hot image. A Duncan Multiple Range Test indicates that only this difference for the VULCAN is significant (p <.05). Of the individual vehicle differences favoring black hot images, that test indicated that only the differences for the Quarter Ton and M477 were significant (p <.05).

As with other effects, identification performance among vehicles varies with thermal image range [F(22,726) = 48.72, p <.001]. Means and standard deviations of the number of slides identified for each vehicle at each range are summarized in Table 5.

Table 5

Means and Standard Deviations of the Number of Slides Identified in the Post-Test for Each Vehicle at Each Range (n=34)

	Range					
	Near		Medium		Far	
Vehicles	Mean*	Standard Deviation	Mean*	Standard Deviation	Mean*	Standard Deviation
M113	5.74	.67	5.50	.83	4.21	1.07
M60	5.62	.65	4.41	1.26	5.21	.84
M1	5.71	.58	3.82	.80	4.97	1.19
Quarter Ton	4.00	1.39	5.00	.65	4.94	1.01
M35(2 1/2 T)	4.12	1.47	5.09	1.26	4.06	1.50
M109	5.06	1.07	2.09	1.22	2.82	1.64
M548	5.62	.78	1.32	1.09	2.26	1.46
VULCAN	5.12	1.17	1.88	1.07	1.26	1.05
M577	3.44	.89	1.76	1.39	2.15	1.08
M880	3.18	1.27	2.41	1.26	1.65	.95
Gamma Goat	4.74	.83	1.12	1.20	.29	.46
CHAPARRAL	4.62	1.13	.79	.91	.47	.61

* Maximum score = 6.

It appears from a review of Table 5 that identification of thermal images of vehicles, with increases in range, depends on the vehicle. Vehicles such as the M113, M60, M1, Quarter Ton and M35 (2 1/2 T) remain discernable with increases in range; however, ability to identify the remaining vehicles is notably reduced as range increases.

Estimating Strength of Association

It is generally understood that statistical significance does not necessarily imply importance. We have seen in all tests reported in previous sections that each is highly significant statistically. In order to assess the importance of each of those reported effects, it is relevant to report the ω^2 statistic to provide an estimate of the proportion of variance in the identification performance which can be accounted for by those effects (See Table 6).

Table 6

Estimation of Strength of Association (ω^2) by Proportion of Variance in Effects Studied Accounted for by Identification Performance

Effects Studied	Proportion of Variance
Polarity	.0034
Polarity x Range	.0022
Range	.1459
Vehicles	.2644
Vehicles x Polarity	.0240
Vehicles x Range	.1354

While earlier presented findings indicate that each of the above effects evidence significant differences, it appears that the most important effects which contribute to variability in data come from effects involving Vehicles and Range; differences in image polarity while contributing to significant performance differences are less important in these data.

Characteristics of "Performers" and "Non-Performers"

As noted in the Method section, only post-test performance of soldiers whose post-training identification performance was greater than or equal to 80% ("Performers") was studied. In order to better understand the background characteristics of soldiers who do well in R&I training, frequency and percent of cases in each of several background category factors were calculated for both performers and non-performers (Table 7). Since the frequencies for many categories were small and could lead to expected values less than 5, Chi-Square tests were not performed. However, review of these data suggest that performers compared to non-performers:

- were higher in rank
- held 19K MOS more and 11M MOS less
- had significantly higher GT [$\underline{F}(1,92) = 10.93$, $\underline{p} = .001$]
- rated themselves less qualified in use of thermal sights
- received thermal imagery training more frequently in the M1 TIS sight rather than the Bradley ISU
- used thermal imagery more often in his job

The majority of both performers and non-performers report black hot images easier to use. This was especially true for performers.

No marked differences were noted between performers and non-performers in:

- age
- use/non-use of glasses
- thermal imagery training received at Fort Hood
- receiving and passing a night vision test

Table 7

Background Characteristics of "Performers" and "Non-Performers"

BACKGROUND CHARACTERISTICS	PERFORMERS		NON-PERFORMERS	
	f	%	f	%
Rank				
1	0	0.00	1	1.64
2	1	2.94	4	6.56
3	2	5.88	18	29.51
4	19	55.88	25	40.98
5	11	32.35	10	16.39
6	1	2.94	3	4.92
	X = 4.26		X = 3.79	
	PERFORMERS		NON-PERFORMERS	
Age	f	%	f	%
18	0	0.00	1	1.64
19	4	11.76	3	4.92
20	6	17.65	10	16.39
21	4	11.76	14	22.95
22	2	5.88	6	9.84
23	5	14.71	9	14.75
24	3	8.82	6	9.84
25	0	0.00	3	4.92
26	4	11.76	2	3.28
27	2	5.88	0	0.00
28	3	8.82	2	3.28
29	0	0.00	0	0.00
30	0	0.00	1	1.64
31	1	2.94	0	0.00
32	0	0.00	0	0.00
33	0	0.00	2	3.28
34	0	0.00	2	3.28
	X = 23.06		X = 22.93	
	PERFORMERS		NON-PERFORMERS	
Duty MOS	f	%	f	%
11M	9	26.47	24	39.34
19D	1	2.94	7	11.48
19K	24	70.59	30	49.18

Table 7 cont'd

Table 7 cont'd

Glasses on Job	PERFORMERS f	PERFORMERS %	NON-PERFORMERS f	NON-PERFORMERS %
Yes	10	29.41	17	27.87
No	24	70.59	44	72.13

GT	PERFORMERS f	PERFORMERS %	NON-PERFORMERS* f	NON-PERFORMERS* %
<89	1	2.94	19	31.67
90-109	17	50.00	26	43.33
110 & up	16	47.06	15	25.00
*One case missing				
		X = 106.68		X = 97.43

Level Qualified R&I Thermal Sight	PERFORMERS f	PERFORMERS %	NON-PERFORMERS f	NON-PERFORMERS %
Not	9	26.47	10	16.39
Some	12	35.29	25	40.98
OK	9	26.47	21	34.43
Well	4	11.77	3	4.92
Extremely Well	0	0.00	2	3.28

Source of Thermal Imagery Training	PERFORMERS f	PERFORMERS %	NON-PERFORMERS f	NON-PERFORMERS %
Service School	3	8.82	5	8.20
Unit Training	6	17.65	15	24.59
OJT	12	35.29	22	36.07
No Training	10	29.41	13	21.31
Other	3	8.82	6	9.84

Thermal Imagery System Trained On	PERFORMERS* f	PERFORMERS* %	NON-PERFORMERS* f	NON-PERFORMERS* %
M60 TTS	1	3.03	0	0.00
M1 TIS	24	72.73	32	53.33
Bradley ISU	6	18.18	18	30.00
ITV TOW	0	0.00	1	1.67
Ground Mounted TOW	0	0.00	2	3.33
Other	2	6.06	7	11.67

*one case missing

Table 7 cont'd

Table 7 cont'd

Thermal Sight R&I Training Type at FH	PERFORMERS f	%	NON-PERFORMERS f	%
35mm Slides	2	5.88	4	6.56
Picture Photos	0	0.00	4	6.56
In Field With Thermal Sight	15	44.12	28	45.90
Other	3	8.82	5	8.20
"Blank" or No FH Training	14	41.18	20	32.79

Tested for Night Vision	PERFORMERS f	%	NON-PERFORMERS f	%
Yes	10	29.41	20	33.90
No	24	70.59	39	66.10

If Tested for Night Vision Did You Pass?	PERFORMERS f	%	NON-PERFORMERS f	%
Yes	9	26.97	18	29.51
No	4	11.76	7	11.47
"Blank"	21	61.76	36	59.02

What Do You Use For R&I	PERFORMERS f	%	NON-PERFORMERS* f	%
Black Hot	20	58.82	29	49.15
White Hot	7	20.59	6	10.17
Both	3	8.82	1	1.69
Neither or NR	4	11.76	23	38.98

*Two cases missing

Which Images are Easier to Use	PERFORMERS f	%	NON-PERFORMERS* f	%
Black Hot	26	76.47	34	57.63
White Hot	2	5.88	5	8.47
Neither	2	5.88	1	1.69
No Response	4	11.76	19	32.20

*Two cases missing

DISCUSSION OF FINDINGS

Image Polarity Setting

As noted earlier, the current research was designed primarily to provide performance-based information about which polarity setting is most useful for the vehicle identification task and at which range. Results of the current research indicate that, statistically speaking, overall identification performance using black hot images was significantly better (p <.001).

Contrary to expectation, results indicate that although absolute performance differences favored black hot images over all ranges, it was only at the near (800-1200 meters) range that significant differences occurred. The failure to find the predicted divergence of black hot and white hot performance curves with increasing range probably can be explained, in part, by a general lack of sufficient cues at the more distant ranges to permit reliable identification of images in either black hot or white hot polarity.

The results also indicate that all vehicles may not be easier to identify with black hot images. Specifically, performance using white hot images of the M1, M35, VULCAN, Gamma Goat and Chaparral were higher; this difference was significant for the VULCAN (p < .05). These findings suggest that while shape may be the primary cue used in identifying thermal images, some vehicles may show particular variations that are more easily discerned with the white hot image. These findings suggest the possibility that once detection occurs in an environment calling for use of thermal imagery, the image polarity setting should initially be set to black hot to effect recognition and identification (R&I). Should R&I not be accomplished in a timely fashion with this setting, the R&I task could be continued by adjusting the contrast and brightness settings until the specific differentiating features are highlighted. If still unsuccessful, a switch to the white hot polarity could be made and followed with the adjustment procedure used with black hot. Further research that would be of value should address which vehicles (and type) have characteristics that are revealed best with different black hot and white settings.

In as much as significance tests of mean differences alone can provide a misleading impression concerning the importance of effects studied, the proportion of variance accounted for in each effect of the post-test identification performance was determined by use of the statistics ω^2. It became clear upon inspection of the statistical results that polarity, polarity in combination with range, and polarity in combination with vehicles together account for less than 3% of the variability in the post-test identification performance. On the other hand, with over 75% of the soldiers stating that black hot images are easier to use and the statistically significant performance difference favoring black hot images, our original hypothesis concerning the relative efficacy of black hot imagery for R&I cannot be rejected. However, these differences compared to vehicle and range differences (individually and in combination) may be of relatively little practical importance.

Range

Previous research involving R&I with thermal images (Smith, et al. 1983, in press) has indicated that performance drops off quite rapidly as range increases. Consistent with that research, the current findings also show that performance drops significantly with increases in range. In this research those differences evidence themselves after vehicles are beyond the range band of 800 to 1200 meters. Whereas performance as a function of range with photopic images is relatively insensitive to ranges from 1000 to 3000 meters (Heuckeroth et al. 1984, in press), performance differences for thermal images are not only statistically significant over a rather narrow absolute range band, but these differences also appear relatively important; approximately 15% of the post-test identification performance variability is accounted for by this factor. Since photopic images generally have more cues to aid in differentiating among vehicles compared to thermal images, these findings are not surprising. As range increases, the number of cues that can be used for distinguishing among vehicles decreases; the fewer the number of cues, the sooner performance degradation would be expected as range increases.

Vehicles and Range

Previous research (Smith et al. 1983, and Heuckeroth et al. 1982) evaluating R&I performance using both thermal and photopic images has demonstrated that some vehicles are easier to learn than others. While the current research uses a different set of vehicles compared to earlier work, the findings are essentially the same. Since shape is the primary distinguishing feature for identifying thermal images of vehicles, we can infer that the shape is more clearly discernable for some vehicles and, therefore, easier to learn. When a factor continues to evidence significant statistical differences across several studies, reliability of the finding is certainly implied, and its importance is suspected. In the current work, the factor of vehicles alone accounts for over 26% of the post-test identification performance variability. Since the number of cues available in thermal images which can be used to facilitate discrimination are much fewer than for the photopic images, it would be desireable to determine whether performance difference among vehicles might be reduced if some mnemonic were used for each vehicle.

In addition to overall performance differences for vehicles, current research has also demonstrated that performance degradation with increases in range is not uniform for all vehicles. As pointed out in the Results section of this report, the M113, M60, M1, Quarter Ton and M35 remain relatively immune to performance differences with increases in range. Compared with the remaining seven vehicles trained, one might infer that the shape of these vehicles is sufficiently large or unique to remain distinguishable even when range increases. It is also possible that these vehicles are generally more familiar to soldiers compared to the remaining vehicles. As with vehicles and range considered independently, these two factors when combined account for approximately 14% of the post-test identification performance variability.

Conclusions

- The black hot thermal polarity setting is preferred for target identification by the majority of soldiers who are competent in vehicle recognition and identification using thermal sights.

- Although an average of absolute differences between performance using black hot images and performance using white hot images favored black hot images across all ranges these results are inconclusive. Further research is suggested.

- Identification performance using thermal images degrades sharply at intermediate ranges (1300 meters) and far ranges (1800-2300 meters).

REFERENCES

Heuckeroth, O.H., Shope, G.L. and Smith, N.D. A detailed evaluation of a new approach to target acquisition training: The combat vehicle identification (CVI) training program. Fort Hood, TX, U.S. Army Research Institute for the Behavioral and Social Sciences. In Preparation.

Lyons, L.E., and Miller, E.E. (1982) Combat vehicle identification (CVI) flashcard evaluation experiment. Human Resources Research Organization, FR-MTLD(TX)-82-17.

Lyons, L.E., Miller, E.E., and Bennett, M.J. (1982) Target identification for RPV operators, Human Resources Research Organization, FR-MTLD(TX)-82-19.

Smith, N.D., Heuckeroth, O.H., Warnick, W.L., and Essig, S.S. (1980) Evaluation of a new approach to target acquisition training: The combat vehicle identification (CVI) training program. Fort Hood, TX, U.S. Army Research Institute for the Behavioral and Social Sciences, Research Report No. 1304. ADA 111732.

Smith, N.D., Shope, G.L., Heuckeroth, O.H., Warnick, W.L., and Essig, S.S. Target acquisition and analysis training systems: Evaluation of the basic thermal combat vehicle identification (TCVI) training program. Fort Hood, TX, U.S. Army Research Institute for the Behavioral and Social Sciences. *Research Report No. 1378.* In Preparation.

Smith, N.D., Shope, G.L., Heuckeroth, O.H., Warnick, W.L., and Essig, S.S. Target acquisition and analysis training system: Effects of motion on performance on the combat vehicle identification (CVI) training program. Fort Hood, TX, U.S. Army Research Institute for the Behavioral and Social Sciences, In Preparation.